THE JOURNAL OF TROPICAL LIFE SCIENCE
VOL. 3, NO. 3, pp. 182 – 186, September, 2013

The assessment of land exploitation by enumerating microbial population: Case study in several locations at Dieng Plateau

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ABSTRACT

Agricultural intensification program in Indonesia which is carried out by using high yield variety, high chemicals use and soil disturbances tends to trigger land exploitation. Land exploitation, performed without considering the land's capability can generate degradations on the land itself. Various methods have been used to determine land exploitation level, including evaluation of soil microbe resources as on soil component. This research is aimed to assess land exploitation level, based on the amount of microbial population. The result of this research is expected to add the soil quality standard criteria. In the case study performed in Dieng plateau, representative soil sampling method was used. The amount of microbial population can be enumerated using plating and MPN method. Based on nutrient availability to indicate the soil biological characteristics, the soil under the trees, shrub, and Colocasia were classified as "below normal", and the soil under the grass, tobacco, cabbage and potato were classified as "normal". It shows that the land exploitation at the agricultural soils were still in the range of its land capability.

Keywords: *land exploitation, soil quality, soil microbe*

INTRODUCTION

Land degradation at Dieng plateau occurs as the result of agricultural application which does not follow the principle of land conservation. At the potato and cabbage land, the row is created in the same direction as the slope (cross contour ridging), supported by high rain intensity so that the erosion is very high and it caused the loss of NPK substances [1]. Besides that, generally inputs such as pesticides, organic and chemical fertilizers are high. The most likely reason is unbalanced nutrients in the soil, decreased soil fertility, and generally tends to trigger land exploitation. Land exploitation, performed without considering the land's capability can generate degradations on the land itself. The land quality standard criteria will be needed to maintain the sustainability of crop production in agricultural soil.

Soil is one of land components, not only a solid medium that holds nutrients for plant growth but have many important functions. One strategy to prevent soil degradation is by conserving and enhancing soil quality as a fundamental first step on environmental improvement. [2]. Soil quality has been pro- posed as a prime indicator for characterizing and defining management factors contributing to soil degradation [3]. Soil quality has been described the combination of chemical, physical and biological characteristics that enables soils to perform a wide range of functions.

The following as availability of nutrients factors: soil microbes (fungi and bacteria), using the indicator of soil respiration, and soil fauna (earthworms, insects, and arthropods), using the indicator of soil fauna population [4]. Biological indicators such as soil respiration, fluorescent *Pseudomonas* bacteria and entomopathogenic nematode populations [3], microbial biomass, respiration, metabolic quotient (qCO_2), dehydrogenase, and phosphatase enzyme activity as well as pH, organic carbon (%C) [5] were used to determine soil quality. There were tried to select test indicators. Several soil biological indicators were rejected due to the high cost of analysis, so that it only used these indicators: organic matter, active carbon, potentially mineralizable of nitrogen, and root health rating [6]; lately, an

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increase in the use of soil microbial parameters has occurred [7].

There has described in this report about population of soil beneficial microbial population (total numbers, phosphate dissolving-microbes, nitrite and nitrate forming bacteria, and sulfur oxidizing fungi) as soil biological indicators. They were separated by two population groups (e.g. bacteria and fungi). Soil microbes and soil fauna that is capable to decompose soil organic matter and releasing or immobilizing plant nutrients. Their decomposi tion activities measures as soil respiration rate to assess by CO2 evolution is an indicator of soil biology. In soil environment, apart from the beneficial micro-organisms able to degrade organic matter, they have the ability to make nitrification activity [8], dissolve inorganic phosphates [9-10], oxidizing-reduced sulfur to sulfate [11] can influence nutrients availability in the soil directly. Their population showed each role in releasing nutrient.

The assessment of soil quality requires quantification of critical soil attributes. Initial measurements of soil quality attributes should be made in high and low productivity areas to establish ranges of values that are site specific [4]. In this paper, they were taken from natural vegetation growing soils and agricultural soils in Dieng plateau area.

MATERIALS AND METHODS

Soil samples

The top of three natural vegetation growing soils and four agricultural soils were collected from sites near three natural sulfur sources at Dieng Mountain, Central Java, Indonesia. The locations and some properties of these soils are listed in Table 1. At each location, a composite sample was taken from the top (0-15 cm) of soil.

Population of microbes

The plates of Czapek-Dox agar medium and nutrient agar were used to determine total numbers of fungi and bacteria, respectively, in each composite soil sample. The plates of Pikovskaya's agar medium were used to determine the numbers of phosphate-dissolving fungi and bacteria. The population of nitrifying bacteria enumerated by MPN method in ammonium-calcium carbonate liquid medium was used for ammonium oxidizers and nitrite-calcium carbonate liquid medium was used for nitrite-oxidizing bacteria [8]. Each tube added with sulfanilic acid and α-naphthylamine solution as nitrite test indicator, and brucine as nitrate test indicator. Sulfur-oxidizing fungi were determined using a modified Czapek-Dox agar medium containing sulfur powder [12]. Serial-dilution methods were used to take a count of all numbers, with 1 ml of each dilution series being spread in the agar plates and in the liquid medium for nitrifying bacteria. Further enumeration was done by colony forming unit counts and cells/g of soil.

Table 1. Locations and some properties of the soil samples

Natural-sulfur source	Plant	Soil name	Texture	pH
		Natural soils		
Telaga Warna	Grass	Andisol	silty loam	4.7
Telaga Warna	Trees	Andisol	silty loam	4.1
Sikidang	Shrub	Andisol	sandy loam	3.9
		Agricultural soils		
Sileri	*Colocasia*	Andisol	clay loam	3.9
Sikidang	Tobacco	Andisol	sandy clay loam	4.2
Sikidang	Cabbage	Andisol	sandy clay loam	4.4
Sileri	Potato	Andisol	clay loam	4.4

Indicating soil biological characteristics based on nutrient availability classification

The nutrient availability for indicating soil biological characteristics as one of the attributes of soil quality indicators was classified as follows in Table 2.

Table 2. Classification of Nutrient Availability

Classification	Nutrient Availability	Soil Condition
Below normal	Low releasing or Immobilizing plant nutrients	Soil has no or low biological activity
Normal	Medium to idel re leasing or immobili zing plant nutrient	Soil is an ideal state of biological activity and active popu lations of beneficial microorganisms
Above normal	High to toxic plant nutrients	Soil has very high level of microbial activity and bloo ming specific micro organisms

To classify the nutrient availability in three level (above normal, normal, below normal) nine criteria were considered, they are: total numbers of fungi, total numbers of bacteria, numbers of phosphate dissolving fungi, numbers of phosphate dissolving bacteria, numbers of nitrite forming bacteria, numbers of nitrate-forming bacteria, numbers of sulfur-oxidizing fungi, respiration rate, total numbers of earth-worm. Assuming that each criteria has three distinct values: 0, 1 and 2, by counting the total value all over the criteria, it will result a certain number that refers to one classification [13].

Table 3.Criteria value for classifying the nutrient availability

Criteria	Value		
	0	1	2
Total numbers of fungi (10^3cfu.g^{-1})	<50	50-100	>100
Total numbers of bacteria (10^4 cell g^{-1})	<100	100-200	>200
Phosphate-dissolving fungi (10^3cfu.g^{-1})	<100	100-200	>200
Phosphate dissolving bacteria (10^4 cell g^{-1})	<10 0	100-200	>200
Nitrite-forming bacteria (10^4 cell g^{-1})	<1	1-25	>25
Nitrate-forming bacteria (10^4 cell g^{-1})	<1	1-25	>25
Sulfur-oxidizing fungi (10^3cfu.g^{-1})	<50	50-100	>100
Respiration rate (kg.CO_2-C/ha/day) [6]	<36	36 - 72	> 72
Earthworm (worms/m^2) [14]	<100	100-200	>200

Assuming that each the criteria have three distinct values, 0, 1 and 2, by counting the total value all over the criteria (Table 3), it will result a certain number that refers to one classification [13]. The total value was compared to the scale of nutrient availability classification, which is: above normal, scale >12; normal, scale 6-12; and below normal, scale <6.

RESULTS AND DISCUSSION

Fungi and bacteria population.

Table 4 figures out the numbers of microbes. The highest total number of fungi was found in grass soil cover, and the highest total number of bacteria was found in tobacco area. In the cabbage and potato cultivated soil bacteria dominated the microbe population. The little number of fungi was found in these soils. These indicate that the bacteria deplete the growth of fungi. It might be caused by the excessively used of fungicides and other pesticides on agricultural practices. The numbers of fungi and bacteria in the natural soil under the trees are 29.33x103 cfu g-1 and 20.0x104 cfu g-1. A different result is reported that the population of culturable bacteria in the forest floor layer of coniferous trees is 5.28x107 cfu g-1 [15].

Phosphate-dissolving fungi and bacteria.

Generally in the natural soil the numbers of the fungi are higher than in the agricultural soil, but the numbers of bacteria are high in the agricultural soil except in the soil which is planted by Colocasia. Bacteria which are found in soil under the trees and shrub were very less till not detected.

To indicate the phosphate availability should be done by counting the number of each dissolver. In the soil under the trees and shrub, the organic source depends on tree litter which contains more lignocelluloses. Fungi Penicillium sp can degrade cellulose [11], besides, it also has a characteristic that can dissolve phosphate because it can produce citric and oxalic acid [16]. These organic acids are the products of organic material degrading process.

Table 5. The value of nutrient availability criteria

Vegetation	TNF	TNB	PDF	PDB	NiFB	NaFB	SOF	RR*	NE*	Total Value	Classification
Natural soil											
Grass	1	0	2	0	1	1	1	2	2	10	normal
Trees	0	0	2	0	1	1	0	0	0	4	below normal
Shrub	0	0	1	0	1	1	0	0	0	3	below normal
Agricultural soil											
Tobacco	0	2	2	2	1	1	0	1	1	10	normal
Colocasia	0	0	0	0	1	1	0	1	1	4	below normal
Cabbage	0	2	0	2	1	1	0	2	1	9	normal
Potato	0	2	0	2	0	1	0	2	1	8	normal

Note: * assumption, TNF: total numbers of fungi, TNB: total numbers of bacteria, PDF: phosphate dissolving fungi, PDB: phosphate dissolving bacteria, NiFB: nitrite-forming bacteria, NaFB: Numbers of nitrate-forming bacteria, SOF: sulfur-oxidizing fungi, RR: Respiration Rate, NE: numbers of earthworm.

While in the agricultural soil which is usually treated by organic fertilizer such as compost or manure which has had decomposition is overgrown with bacteria including phosphate-dissolving bacteria. Two hundred and seven bacteria were isolated from farm waste compost and Gliricidia vermi-compost, including phosphate dissolving bacteria [9].

The high population of phosphate-dissolver demonstrated the higher availability of phosphate. However, phosphate dissolving microbes were not the only factors which determine the bioavailability of phosphate. Arbuscular mycorrhizal fungi and N2 fixing bacteria together with phosphate dissolving rhizobacteria help in the uptake of tri calcium phosphate. These rhizobacteria behaved as “mycorrhiza helper” and enhanced root colonization by mycorrhiza in presence of tri calcium phosphate) [10].

Nitrifying bacteria

There are two kinds of nitrifying bacteria, i.e. nitrite and nitrate forming bacteria. The existing of nitrifying bacteria changes the ammonium to nitrate in soil by oxidation process. In this study there is no significant difference between natural and agricultural soils. The soil which is examined has pH 3,9-4,7, under the optimum pH for nitrifying bacteria activity (pH 5-8). Agricultural soil is often treated by large amount of urea fertilizer. It indicates the presence of a pH-dependent uptake system for urea. Simultaneous oxidation of free ammonia, possible only at high pH values, led to a strong intensification of ureolysis [17].

The higher population of nitrifying bacteria means the higher nitrate in oxidative soil. The N-mineralization, the nitrification and the viable number of nitrifying cells were consistently higher for forest soils compared to savanna sites (grassland). Soil microbial process (N-mineralization and nitrification) and nitrifying population size were dependent on site topography, vegetation cover and status of soil moisture [8].

Sulfur-oxidizing fungi. The fungi are able to oxidize reduced-sulfate (S0) to sulfate (SO4). The higher population of sulfur-oxidizing fungi shows higher availability of sulfate. In grass soil cover, the highest population of sulfur-oxidizing fungi was found. In cabbage and potato cultivated soil the fungi was not detected, it might be caused the frequent use of fungicides and other pesticides. Sulfur-oxidizing fungi which are found in natural soil are species Aspergillus and Penicillium. Fungi Penicillium has a better resistance to the use of agrochemical which is applied in the agricultural soil [18].

Classification of nutrient availability. Based on nine criteria to classify the nutrient availability in natural and agricultural soils, the total values for each plant soil cover are shown in Table 5. The results are that the soil under grass, tobacco, cabbage and potato are classified as normal nutrient availability, and soil under trees, shrub and Colocasia are classified as below normal nutrient availability.

The normal classification means that soil is in ideal state of biological activity and active populations of beneficial micro-organisms. Native grassland has higher soil organic matter and nitrogen concentrations than the soil after processed for agricultural purpose, however, pH, EC, and extractable soil P, K, Ca, Mg, Fe are significantly higher under tilled agriculture [19]. The land exploitation in these area were still in the range of its land capability, though the soil under tobacco, cabbage and potato were tilled and applied of high fertilizers (organic and inorganic) and pesticides. A different result that the soil quality which is grown by potato is low based on biology indicators in the form of organic matter, active carbon, potential mineralized nitrogen, and root health rate [6]. This difference indicates that the population of soil beneficial microbes is still normal in the agricultural soil however soil tillage in the agricultural soil causes faster degrading process of organic matter and nitrogen oxidation by the nitrifying bacteria. The soil quality value becomes lower as the result of organic matter changing which decreases the soil organic matter and N-mineral, which is mostly in the form of nitrate, is easy to dissolve through water flow and soil erosion. Actual erosion that occurs on soil which is grown by potato and cabbage respectively are 48.831 tons/ha/year and 65.573 tons/ha/year, causes the loss of nitrogen by 110.25kg/ha and 130.46kg/ha per planting season [1].

The below normal classification means that soil has no or low biological activity. The soil under the trees, shrub and Colocasia were not given fertilizers (chemical and organic), and there were no or minimum tillage. In these areas, the soil is almost undisturbed from human activity. Hence, the land has not been exploited. Total population of microorganism, phosphate dissolver, and sulfur oxidizer in these soils are low. This possibility has a relation with the entering process of organic matter as the carbon sources in the surface of no-tillage soil which derives from the litter. The soil microbial biomass under no-tillage was greatest at the 0- to 5-cm depth with 50% less in the 5- to 20-cm depth, and least in the 20- to 30-cm depth [20]. The biomass of microbial groups within the soil profile was affected by tillage treatment, soil depth, and time after one-time tillage.

The value of nutrient availability can be possibly changed in accordance with the change of input treatment per time and per location. There is also a need to quantify the soil variability and determine the scales of its occurrences if we want to optimize resource allocations. Real-time assessment of spatial variability allows differential application and treatment of chemicals, pesticides, irrigation water and waste products on small site-specific areas [21].

CONCLUSION

Based on nutrient availability to indicate the soil biological characteristics, the agricultural soils were classified as “normal”. To assess the land exploitation, physical, chemical and biological characteristics of soil should be considered. This research was only focused on beneficial micro-organisms population to complete soil biological indicators. It is a suggested to bring all together the soil characteristics to obtain the accurate assessment.

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